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Lisa PALMQVIST et al.
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## CLAIM FOR CONVENTION PRIORITY

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

The benefit of the filing date of the following prior foreign application in the following foreign country is hereby requested, and the right of priority provided in 35 U.S.C. § 119 is hereby claimed:

Swedish Patent Application No. 9900403-8

Filed: February 5, 1999

In support of this claim, enclosed is a certified copy of said prior foreign application. Said prior foreign application is referred to in the oath or declaration. Acknowledgment of receipt of the certified copy is requested.

Respectfully submitted,

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# Cemented carbide insert

The present invention relates to a coated cutting tool insert particularly useful for turning of steel, like low alloyed steels, carbon steels and tough hardened steels at high cutting speeds. The insert is based on WC, cubic carbides and a Co-binder phase. It has surface zones with element compositions differing from the bulk composition giving simultaneously an excellent resistance to plastic deformation and high toughness performance.

High performance cutting tools must nowadays possess high wear resistance, high toughness properties and good resistance to plastic deformation. This is particularly valid when the cutting operation is carried out at very high cutting speeds and/or at high feed rates when large amount of heat is generated.

Improved resistance to plastic deformation of a cutting insert can be obtained by decreasing the WC grain size and/or by lowering the overall binder phase content, but such changes will simultaneously result in significant loss in the toughness properties of the insert.

Methods to improve the toughness behaviour by introducing a thick essentially cubic carbide free and binder phase enriched surface zone with a thickness of about 20-40 µm on the inserts by a so called gradient sintering techniques are known.

However, these methods produce a rather hard cutting edge due to a depletion of binder phase and enrichment of cubic phases along the cutting edge. A hard cutting edge is more prone to chipping. Nevertheless, such carbide inserts with essentially cubic carbide free and binder phase enriched surface zones are extensively used today for machining steel and stainless steel.

There are ways to influence the plastic deformation resistance and toughness properties to a certain extent by controlling the carbide composition along the cutting edge by employing special sintering techniques or by using certain alloying elements e.g. US 5,484,468, US 5,549,980 and US

5,729,823 or EP-A-569,696. All these techniques give a binder phase enrichment in the outermost region of the edge. However, inserts produced according to these techniques often obtain micro plastic deformation at the outermost part of the cutting edge. In particular, this often occurs when the machining is carried out at high cutting speeds. A micro plastic deformation of the cutting edge will cause a rapid flank wear and hence a shortened lifetime of the cutting inserts. A further drawback of the above-mentioned techniques is that they are complex and difficult to fully control.

US 5,786,069 and EP-A-753 603 disclose coated cutting tool inserts with a binder phase enriched surface zone and a highly W-alloyed binder phase.

Figure 1 is a schematic drawing of a cross section of an edge of an insert gradient sintered according to the present invention where

A = binder phase enriched surface zone

B = cutting edge near zone

C = a line essentially bisecting the edge

It has now surprisingly been found that significant improvements with respect to resistance to plastic deformation and toughness behaviour can simultaneously be obtained for a cemented carbide insert if a number of features are combined. The improvement in cutting performance of the cemented carbide inserts can be obtained if the cobalt binder phase is highly alloyed with W, if the essentially cubic carbide free and binder phase enriched surface zone A has a certain thickness and composition, if the cubic carbide composition near the cutting edge B is optimised and if the insert is coated with a 3-12 µm columnar TiCN-layer followed by a 2-12 µm thick $Al_2O_3$-layer e.g. produced according to any of the patents US 5,766,782, US 5,654,035, US 5,674,564 or US 5,702,808. The $Al_2O_3$-layer will serve as an effective thermal barrier during cutting and thereby improve not only the resistance to plastic deformation which is a heat influenced property but also increase the crater wear resistance of the cemented carbide insert. In addition, if the coating along the cutting edge is smoothed by an appropriate technique like by brushing with a

SiC-based nylon brush or by a gentle blasting with $Al_2O_3$ grains the cutting performance can be enhanced further, in particular with respect to flaking resistance of the coating (see Swedish patent application 9402543-4).

Said cutting insert possesses excellent cutting performance when machining steel at high cutting speeds, in particular low alloyed steels, carbon steels and tough hardened steels. As a result a wider application area for the coated carbide insert is obtained because the cemented carbide insert according to the invention performs very well at both low and very high cutting speeds under both continuous and intermittent cutting conditions.

According to the present invention there is now provided a coated cemented carbide insert with a <20 µm, preferably 5-15 µm, thick essentially cubic carbide free and binder phase enriched surface zone A (Fig.1) with an average binder phase content (by volume) of 1.2-3.0 times the bulk binder phase content. In order to obtain high resistance to plastic deformation but simultaneously avoid a brittle cutting edge the chemical composition is optimised in zone B (Fig.1). Along line C (fig. 1), in the direction from edge to the centre of the insert, the binder phase content increases essentially monotonously until it reaches the bulk composition. At the edge the binder phase content is 0.65-0.75, preferably about 0.7 times the binder phase content of the bulk. In a similar way, the cubic carbide phase content decreases along line C from about 1.3 times the content of the bulk. The depth of the binder phase depletion and cubic carbide enrichment along line C is 100-300 µm, preferably 150-250 µm.

The binder phase is highly W-alloyed. The content of W in the binder phase can be expressed as a

$$\text{CW-ratio} = M_s / (\text{wt-\% Co} \cdot 0.0161) \text{ where}$$

$M_s$ is the measured saturation magnetisation of the cemented carbide body in kA/m and wt-% Co is the weight percentage of Co in the cemented carbide. The CW-ratio takes a value <=1 and the lower the CW-ratio is the higher is the W-content in the binder phase. It has now been found according

to the invention that an improved cutting performance is achieved if the CW-ratio is 0.75-0.90, preferably 0.80-0.85.

Inserts according to the invention are further provided with a coating consisting of essentially 3-12 µm columnar TiCN-layer followed by a 2-12 µm thick $Al_2O_3$-layer deposited e.g. according to any of the patents US 5,766,782, US 5,654,035, US 5,674,564, US 5,702,808 preferably with an $\alpha$-$Al_2O_3$-layer.

The present invention is applicable to cemented carbides with a composition of 2-10, preferably 4-7, weight percent of binder phase consisting of Co, and 4-12, preferably 7-10, weight percent cubic carbides of the metals from groups IVa, Va or VIa of the periodic table, preferably >1 wt% of each Ti, Ta and Nb and a balance WC. The WC has an average grain size of 1.0 to 4.0 µm, preferably 2.0 to 3.0 µm. The cemented carbide body may contain small amounts, <1 volume-%, of $\eta$-phase ($M_6C$).

By applying layers with different thicknesses on the cemented carbide body according to the invention, the property of the coated insert can be optimised to suit specific cutting conditions. In one embodiment, a cemented carbide insert produced according to the invention is provided with a coating consisting of: 6 µm TiCN, 8 µm $Al_2O_3$ and 1 µm TiN. This coated insert is particularly suited for cutting operation with high demand regarding crater wear. In another embodiment, a cemented carbide insert produced according to the invention is provided with a coating consisting of: 8 µm TiCN, 4 µm $Al_2O_3$ and 1 µm TiN. This coating is particularly suited for cutting operations with high demands on flank wear resistance.

The invention also relates to a method of making cutting inserts comprising a cemented carbide substrate consisting of a binder phase of Co, WC and a cubic carbonitride phase with a binder phase enriched surface zone essentially free of cubic phase and a coating. A powder mixture containing 2-10, preferably 4-7, weight percent of binder phase consisting of Co, and 4-12, preferably 7-10, weight percent cubic carbides of the metals from groups IVa, Va or VIa of the periodic table, preferably >1 wt% of each Ti, Ta and Nb and a balance WC with

an average grain size of 1.0-4.0 µm, preferably 2.0-3.0 µm. Well-controlled amounts of nitrogen have to be added either through the powder as carbonitrides or/and added during the sintering process via the sintering gas atmosphere. The amount of added nitrogen will determine the rate of dissolution of the cubic phases during the sintering process and hence determine the overall distribution of the elements in the cemented carbide after solidification. The optimum amount of nitrogen to be added depends on the composition of the cemented carbide and in particular on the amount of cubic phases and varies between 0.9 and 1.7%, preferably about 1.3-1.4%, of the weight of the elements from groups IVa and Va of the periodic table. The exact conditions depend to a certain extent on the design of the sintering equipment being used. It is within the purview of the skilled artisan to determine whether the requisite surface zones A and B of cemented carbide have been obtained and to modify the nitrogen addition and the sintering process in accordance with the present specification in order to obtain the desired result.

The raw materials are mixed with pressing agent and possibly W such that the desired CW-ratio is obtained and the mixture is milled and spray dried to obtain a powder material with the desired properties. Next, the powder material is compacted and sintered. Sintering is performed at a temperature of 1300-1500°C, in a controlled atmosphere of about 50-mbar followed by cooling. After conventional post sintering treatments including edge rounding a hard, wear resistant coating according to above is applied by CVD- or MT-CVD-technique.

## Example 1

**A.)** Cemented carbide turning inserts of the style CNMG 120408-PM, DNMG150612-PM and CNMG160616-PR, with the composition 5.5 wt% Co, 3.5 wt% TaC, 2.3 wt% NbC, 2.1 wt% TiC and 0.4 wt% TiN and balance WC with an average grain size of 2.5 µm were produced according to the invention. The nitrogen was added to the carbide powder as TiCN. Sintering was done at

1450 $^{o}C$ in a controlled atmosphere consisting of Ar, CO and some $N_2$ at a total pressure of about 50 mbar.

Metallographic investigation showed that the produced cemented carbide inserts had a cubic-carbide-free zone A with a thickness of 10 µm. Image analysis technique was used to determine the phase composition at zone B and the area along line C (Fig.1). The measurements were done on polished cross sections of the inserts over an area of approx. 40 x 40 µm gradually moving along the line C. The phase composition was determined as volume fractions. The analysis showed that the cobalt content in zone B was 0.7 times the bulk cobalt content and the gamma phase content 1.3 times the bulk gamma phase content. The measurements of the bulk content were also done by image analysis technique. The Co-content was gradually increasing and the gamma phase content gradually decreasing along line C in the direction from the edge to the centre of the insert.

Magnetic saturation values were recorded and used for calculating CW-values. An average CW-value of 0.84 was obtained.

**B.)** Inserts from **A** were first coated with a thin layer < 1 µm of TiN followed by 6 µm thick layer of TiCN with columnar grains by using MTCVD-techniques (process temperature 850 $^{o}C$ and $CH_3CN$ as the carbon/nitrogen source). In a subsequent process step during the same coating cycle, an 8 µm thick α-$Al_2O_3$ layer was deposited according to patent US 5,654,035. On top of the α-$Al_2O_3$ layer a 1.5 µm TiN layer was deposited.

**C.)** Inserts from **A** were first coated by a thin layer <1 µm of TiN followed by a 9 µm thick TiCN-layer and a 5 µm thick α-$Al_2O_3$ layer and a 2 µm thick TiN layer on top. The same coating procedures as given in A.) were used.

**D.)** Commercially available cutting insert in style CNMG 120408-PM, DNMG150612-PM and CNMG160616-PR, with the composition given below were used as references in the cutting tests:

Composition: Co =5.5 wt%, Ta = 3.5C wt%, NbC = 2.3 wt%, TiC = 2.6 wt% and balance WC with a grain size 2.6 µm.
Cobalt enriched gradient zone: none

CW-ratio: > 0.95

Coating: 8 µm TiCN, 6 µm $Al_2O_3$, 0.5 µm TiN on top

**E.)** Inserts with the same cemented carbide composition as in **D** were coated with 4 µm TiCN and 6 µm $Al_2O_3$. Inserts styles CNMG120408-QM and CNMG120412-MR.

**F.)** Inserts in styles CNMG120408-QM and CNMG120412-MR with the composition: 4.7 wt% Co, 3.1 wt% TaC, 2.0 wt% NbC, 3.4 wt%, TiC 0.2 wt% N and rest WC with a grain size of 2.5 µm were produced. The inserts were sintered according to the method described in patent US 5,484,468 i.e. a method that gives cobalt enrichment in zone B. The sintered carbide inserts had a 25 µm thick gradient zone essentially free from gamma phase. The inserts were coated with the same coating as in **E**.

Example 2

Inserts from **B** and **C** were tested and compared with inserts from **D** with respect to toughness in a longitudinal turning operation with interrupted cuts.

Material: Carbon steel SS1312.

Cutting data:

Cutting speed = 140 m/min

Depth of cut = 2.0 mm

Feed = Starting with 0.12 mm and gradually increased by 0.08 mm/min until breakage of the edge

15 edges of each variant were tested

Inserts style: CNMG120408-PM

Results:

| | Mean feed at breakage |
|---|---|
| Inserts B | 0.23 mm/rev |
| Inserts C | 0.23 mm/rev |
| Inserts D | 0.18 mm/rev |

Example 3

Inserts from **B**, **C** and **D** were tested with respect to resistance to plastic deformation in longitudinal turning of alloyed steel (AISI 4340).

Cutting data:

| | |
|---|---|
| Cutting speed= | 160 m/min |
| Feed= | 0.7 mm/rev. |
| Depth of cut= | 2 mm |
| Time in cut= | 0.50 min |

The plastic deformation was measured as the edge depression at the nose of the inserts.

Results:

| | Edge depression, µm |
|---|---|
| Insert B | 43 |
| Insert C | 44 |
| Insert D | 75 |

Examples 1 and 2 show that the inserts B and C according to the invention exhibit much better plastic deformation resistance in combination with somewhat better toughness behaviour in comparison to the inserts D according to prior art.

<u>Example 4</u>

Inserts from E and F were tested with respect to flank wear resistance in longitudinal turning of ball bearing steel SKF25B.

Cutting data:

| | |
|---|---|
| Cutting speed: | 320 m/min |
| Feed: | 0.3 mm/rev. |
| Depth of cut: | 2 mm |

Tool life criteria: Flank wear $\geq$ 0.3 mm

Results:

| | Tool life |
|---|---|
| Insert E | 8 min |
| Insert F | 6 min |

Variant F exhibited micro plastic deformation resulting in more rapid development of the flank wear.

Example 5.

Inserts from E and F in inserts style CNMG120412-MR were tested at an end user in machining of a steel casting component.

Cutting data:

| | |
|---|---|
| Cutting speed: | 170-180 m/min |
| Feed: | 0.18 mm/rev. |
| Depth of cut: | 3 mm |

The component had the shape of a ring. The inserts machined two components each and the total time in cut was 13.2 min.

After the test the flank wear of the inserts were measured.

Results:

| | Flank wear |
|---|---|
| Insert E | 0.32 mm |
| Insert F | 0.60 mm |

Example 4 and 5 illustrate the detrimental effect of cobalt enrichment in the edge area B typical for inserts produced by prior art gradient sintering technique as described in e.g. US 5,484,468.

Example 6

Inserts from B and D were tested under the same condition as in Example 3. Inserts style CNMG120408-PM

Cutting data:

| | |
|---|---|
| Cutting speed: | 320 m/min |
| Feed: | 0.3 mm/rev. |
| Depth of cut | 2 mm |

Tool life criteria: Flank wear ≥0.3 mm

| Results: | Tool life |
|---|---|
| Insert B | 8 min |
| Insert D | 8 min |

Example 7

Inserts from B and D were tested at an end user in the machining of cardan shafts in tough hardened steel. Insert style DNMG150612-PM.

Cutting condition:

| | |
|---|---|
| Cutting speed: | 150 m/min |
| Feed: | 0.3 mm/rev. |
| Depth of cut: | 3 mm |

The inserts machined 50 component each. Afterwards the flank wear of the inserts was measured.

Results:

| | Flank wear |
|---|---|
| Insert B | 0.15 mm |
| Insert D | 0.30 mm |

Examples 6 and 7 illustrate that inserts with an optimised edge zone B composition according to the invention do not suffer from micro plastic deformation and hence no rapid flank wear as prior art gradient sintered insert F does (see examples 4 and 5).

Example 8

In a test performed at an end-user inserts from B, C and D in style CNMG160616-PR were run in a longitudinal turning operation in machining of crankshaft in low alloyed steel.

The inserts were allowed to machine 90 crankshafts and the flank wear were measured and compared.

Cutting data:

| | |
|---|---|
| Cutting speed: | 220 m/min |
| Feed: | 0.6 mm/rev. |
| Depth of cut | 3-5 mm |
| Total time in cut | 27 min. |

The dominating wear mechanism was plastic deformation of the type edge impression causing a flank wear.

Results:

| | Flank wear |
|---|---|
| Insert B | 0.2 mm |
| Insert C | 0.2 mm |
| Insert D | 0.6 mm |

The example illustrates the superior resistance to plastic deformation of the inserts B and C produced according to the invention compared to prior art inserts D.

## Claims

1. A cutting tool insert for machining of steel comprising a cemented carbide body and a coating c h a r a c t e r i s e d in that

- the cemented carbide body consists of WC, 2-10 wt-% Co and 4-12 wt-% of cubic carbides of metals from groups IVa, Va or VIa of the periodic table, preferably >1% of each Ti, Ta and Nb, whereby N is added in an amount of between 0.9 and 1.7%, preferably about 1.3-1.4%, of the weight of the elements from groups IVa and Va
- the Co-binder phase is highly alloyed with W with a CW-ratio of 0.75-0.90
- the cemented carbide body has a binder phase enriched and essentially cubic carbide free surface zone A of a thickness of <20 µm
- the cemented carbide body has along a line essentially bisecting the edge C, in the direction from edge to the centre of the insert, a binder phase content increasing essentially monotonously until it reaches the bulk composition from a binder phase content at the edge of 0.65-0.75, preferably of about 0.7, times the binder phase content of the bulk whereby the depth of the binder phase depletion is 100-300 µm, preferably 150-250 µm.
- the coating comprises a coating consisting of 3-12 µm columnar TiCN-layer followed by a 2-12 µm thick $Al_2O_3$-layer.

2. A cutting tool insert according to claim 1 c h a r a c t e r i s e d in that the thickness of zone A is 5-15 µm.

3. A cutting tool insert according to claim 1 or 2 c h a r a c t e r i s e d in that the chemical composition of the said cemented carbide body is 4-7 wt-% Co and 7-10 wt-% of cubic carbides.

4. A cutting tool insert according to previous claims c h a r a c t e r i s e d in that the said $Al_2O_3$-layer is $\alpha$-$Al_2O_3$.

5. A cutting tool insert according to any of claim 1-4 c h a r a c t e r i s e d in an outermost layer of TiN.

6. A cutting tool insert according to any of the previous claims c h a r a c t e r i s e d in that the cutting edge is smoothed by brushing or by blasting.

7. A cutting tool insert according to any of claim 1-6 c h a r a c t e r i s e d in that the average WC-grain size is 2.0-3.0 µm.

8. Method of making a cutting insert comprising a cemented carbide substrate with a binder phase enriched surface zone and a coating, said substrate consisting of a binder phase of Co, WC and a cubic carbonitride phase, said binder phase enriched surface zone being essentially free of said cubic carbonitride phase and with an essentially constant thickness around the insert c h a r a c t e r i s e d in forming a powder mixture containing WC, 2-10, preferably 4-7, weight percent Co, and 4-12, preferably 7-10, weight percent cubic carbides of the metals from groups IVa, Va or VIa of the periodic table, preferably >1 wt% of each Ti, Ta and Nb whereby N is added in an amount of between 0.9 and 1.7%, preferably about 1.3-1.4%, of the weight of the elements from groups IVa and Va

mixing said powders with pressing agent and possibly W such that the desired CW-ratio is obtained

milling and spray drying the mixture to a powder material with the desired properties

compacting and sintering the powder material at a temperature of 1300-1500°C, in a controlled atmosphere of about 50-mbar followed by cooling

applying conventional post sintering treatments including edge rounding and

applying a hard, wear resistant coating by CVD- or MT-CVD-technique.

Abstract

The present invention relates to a coated cemented carbide insert for turning of steel, like low alloyed steels, carbon steels and tough hardened steels at high cutting speeds. The cemented carbide consists of WC, 2-10 wt-% Co and 4-12 wt-% of cubic carbides of metals from groups IVa, Va or VIa of the periodic table, preferably Ti, Ta and Nb. The Co-binder phase is highly alloyed with W with a CW-ratio of 0.75-0.90. The insert has a binder phase enriched and essentially cubic carbide free surface zone A of a thickness of <20 µm and along a line essentially bisecting the edge C, in the direction from the edge to the centre of the insert, a binder phase content increases essentially monotonously until it reaches the bulk composition. The binder phase content at the edge is 0.65-0.75 times the binder phase content of the bulk and the depth of the binder phase depletion is 100-300 µm, preferably 150-250 µm. The insert is coated with 3-12 µm columnar TiCN-layer followed by a 2-12 µm thick $Al_2O_3$-layer.

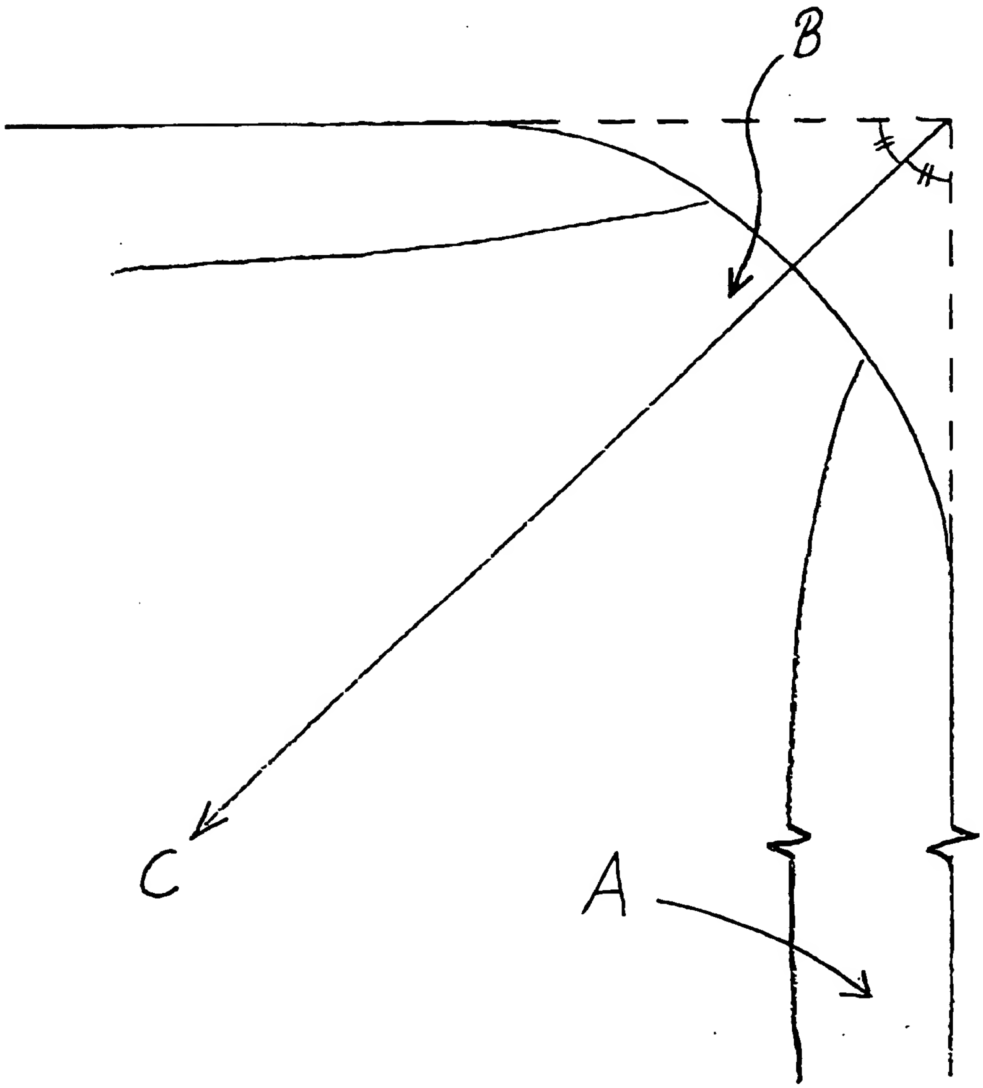


**Fig. 1**